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LOW-AMPLITUDE VARIABLES: DISTINGUISHING RR LYRAE STARS FROM ECLIPSING BINARIES.

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ABSTRACT

It is not easy to identify and classify low-amplitude variables, but it is important that the classification is done correctly. We use photometry and spectroscopy to classify low-amplitude variables in a 246 deg^2 part of the Akerlof et al. (2002) field. Akerlof and collaborators found that 38% of the RR Lyrae stars in their 2000 deg^2 test field were RR1 (type *c*). This suggests that these RR Lyrae stars belong to an Oosterhoff Type II population while their period distribution is primarily Oosterhoff Type I. Our observations support their RR0 (type *ab*) classifications, however 6 of the 7 stars that they classified as RR1 (type *c*) are eclipsing binaries. Our classifications are supported by spectroscopic metallicities, line-broadening and Galactic rotation measurements. Our 246 deg^2 field contains 16 RR Lyrae stars that are brighter than m_R = 14.5; only four of these are RR1 (type *c*). This corresponds to an Oosterhoff Type I population in agreement with the period distribution.

Subject headings: stars: RR Lyrae, stars: horizontal branch, Galaxy: structure, Galaxy: halo

1. INTRODUCTION

Low-amplitude variables are difficult to identify and classify, yet determining their true nature is astrophysically important. Lee and Carney (1999) and Miceli et al. (2008) have shown that the Oosterhoff Type I (Oo I) and the Oosterhoff Type II (Oo II) *field* RR Lyrae stars have different galactic distributions and hence, presumably, different origins. Oosterhoff Types are defined not only by the period distributions of their RR0 (type *ab*) and RR1 (type *c*) variables but also by the relative numbers of these two RR Lyrae types. Thus the RR1 (type *c*) comprise 45% of all the RR Lyrae stars in the Oo II globular clusters but only 20% in the OoI globular clusters (Clement et al. 2001). In recent large surveys for field RR Lyrae stars, RR1 variables comprised 17% of the total in the QUEST Survey (Vivas et al. 2004) and 22% of the total in the SDSS Stripe 82 Survey (Watkins et al. 2009) indicating Oo I populations in both cases.

Akerlof et al.. (2000) (hereafter AAB), on the other hand, study a 2000 deg^2 field of the *ROTSE* All-Sky Survey [2], and find that 38% of their RR Lyrae stars are RR1 (type *c*). Problematically, this suggests an Oo II population although the period distribution shown in AAB (Fig. 8) is that of a predominantly Oo I population. The *QUEST*, *SDSS* and *ROTSE*1 surveys all use CCD photometry which (unlike the older photographic surveys) can be used to detect the relatively low-amplitude RR1 (type *c*) variables with reasonable completeness. The *ROTSE*1 survey, for example, lists variables with amplitudes as low as 0.1 mag—significantly lower than the amplitudes of most RR1 (type *c*). Amrose & McKay (2001) did not include the RR1 (type *c*) in their discussion of the *ROTSE1* RR Lyrae variables because they considered their classification less robust than that of the RR0 (type *ab*). We also note that the stars that AAB classify as RR1 (type *c*) tend to be brighter and to have lower reduced proper motions than those that they classify as RR0 (type *ab*); this suggests that we should review the classification of the lower amplitude RR Lyrae stars in the *ROTSE*1 survey.

Recently, Hoffman et al. (2009) have re-classified the brighter variables in the *NSVS* using Fourier coefficients. Even in this bright sample, they say " without color information and higher precision photometry, the W UMa and RRc variables cannot easily be differentiated" and in their summary they cite the W UMa/RRc degeneracy problem as a major source of misclassification. Blomme et al. (2010) mention the problem in their discussion of the new Kepler data and it surely will be a problem in the pipeline analysis of Pan-STARRS and LSST variable star data.

In this paper we consider a 246 deg^2 field near the North Galactic Pole (NGP) defined by 186.°5< R.A.< 204.°0 and +23.°0< Dec.<+39.°0 (Fig. 1). This is part of the 2000 deg^2 test field *ROTSE*1. In addition to discussing the data given by AAB, we use the General Catalogue of Variable Stars (*GCVS*) (Samus 2005) and various sources discussed in the Appendix (A).

AAB identified 33 RR Lyrae stars in this field; one of these (J130441.22+381804.50) is the same as J130441.18+381805.1 and is ignored. AAB classified 9 as RR1 (type *c*) and 23 as RR0 (type *ab*). Two of these RR1 (U Com and VW CVn) are given in the *GCVS*. U Com has been studied in detail (Bono et al. 2000) and its classification is secure. VW CVn, however, is classified as an eclipsing binary in both the *GCVS* and SIMBAD. It is also included in a recent catalogue of eclipsing variables (Malkov et al., 2006). AAB classify VW CVn as

[1] The NOAO are operated by AURA, Inc. under cooperative agreement with the National Science Foundation.
[2] Hereafter called the *ROTSE*1 survey. We refer to the complete Northern Sky Variability Survey (Wozniak et al., 2004) as the *NSVS*.

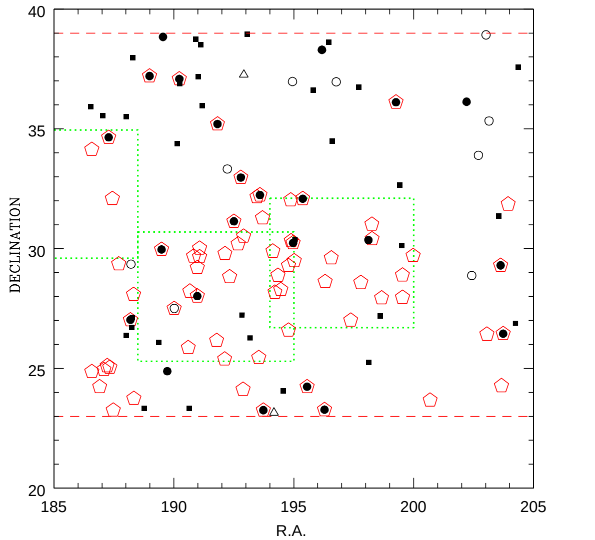

FIG. 1.— Our field at the North Galactic Pole that contains *ROTSE*1 variables lies between Declinations +23.°0 and +39.°0 (shown by the horizontal red dashed lines). The RR Lyrae stars listed in the *GCVS* are shown by large open red pentagons. The stars that were discovered by AAB are shown (using their classifications) by the following black symbols: filled circles RR0 (type *ab*); open circles RR1 (type *c*); open triangles Delta Scuti stars. The small filled squares show the stars that AAB classified as eclipsing binaries. The survey fields of Kinman et al. (1966) are outlined by green dotted lines.

RR1 (type *c*) and it is clear from the light curve given by Agerer and Berthold (1994) that this classification is the correct one with a period of 0.425 days and not (as originally thought) an eclipsing system with twice this period. *This confusion over the nature of a 12th magnitude star shows that the classification of RR1 variables from low S/N data is not trivial.*

The 21 *ROTSE*1 RR Lyrae stars in our field that are in the *GCVS* are listed in Table 1. The *ROTSE*1 data for the other 11 RR Lyrae variables are given in Table 2. Further information on these stars is given in the notes to this table. Apart from VW CVn, we assume that the *GCVS* classifications given in Table 1 are correct but that the classifications of the stars in Table 2 need to checked through new photometry, spectroscopy and a rediscussion of the *NSVS* photometry for these variables.

2. PHOTOMETRY OF VARIABLES

We first observed the variables in Table 2 on 9 nights of a 12-night run with the 42-inch John S. Hall telescope of the Lowell Observatory using the Kron aperture photometer and a thermoelectrically cooled EMI 6256 photomultiplier. Landolt standards (Landolt, 1992) were observed nightly so that the V and $(B-V)$ are on the Johnson system. These observations (made in May 2002; JD 2452407 – 2452418) are given in Table 3. Only about ten observations were obtained for each object. Also, although the sky was apparently clear for these observations, the scatter in the V magnitudes suggests that it may not have always been perfectly photometric. The effect on the $(B-V)$ colors was probably minor in comparison. We therefore obtained further photometric observations between 2004 and 2009 using the commercial robotic f/7 0.8-m Ritchey-Chretien telescope of the Tenagra Observatory in Arizona (Schwartz 2007). The detector on this telescope was a 1024 × 1024 SITe CCD. Only the central 7-arcmin diameter field (which has excellent cosmetic quality) was used and reduced with standard *IRAF* routines (Tody 1993). On photometric nights the data were calibrated using local standards from an earlier program at the North Galactic Pole (Kinman et al., 1994). The variable J123811.00+385028.0 and its comparison star (A) at J123806.03+385049 have also been observed by Schmidt (private communication). He found $V = 13.848$ and $V - R = 0.372$ for the comparison star while we get $V = 13.841$ and $B-V = 0.27$ in satisfactory agreement. On non-photometric nights, the magnitudes of the variables were obtained differentially with respect to nearby stars. The positions of these comparison stars and their adopted magnitudes are given in Table 2 in the Appendix (C). In some cases only relatively faint comparison stars were available in the 7 arcmin field and this limited the attainable accuracy with the relatively short exposures that were used.

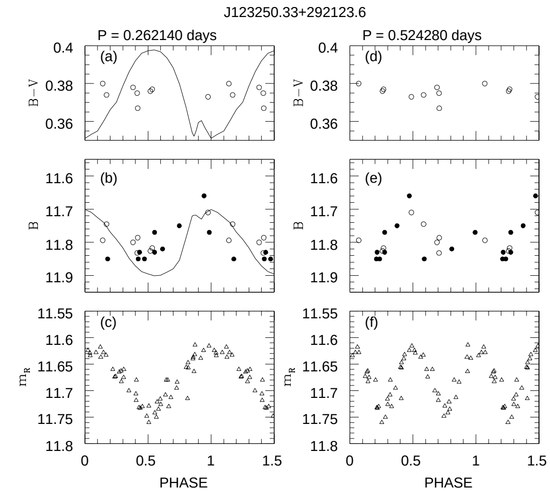

FIG. 2.— Light curves for J123250.33+292123.6. Open circles show the Lowell photoelectric data (2002). Filled circles show the Tenagra CCD photometry (2008, 2009). The open triangles show the light curves derived from *NSVS* photometry (1999, 2000). The plots on the left are for a period of 0.262140 days and those on the right are for a period of 0.524280 days which is the preferred interpretation. The curves in panels (a) and (b) are those that would be expected if the star were an RRc variable; it is seen that they do not fit the data.

The photoelectric data of 2002 are given in Table 3 and the Tenagra photometric data are given in Table 4[3]. We also used the Northern Sky Variability Survey (*NSVS*, Wozniak et al. 2004). Typically, this data contains many pairs of observations that are separated by about 0.0010 days and which can be combined to improve the accuracy with negligible loss of time resolution. We also rejected data if the quoted errors were relatively large.

We illustrate the problem of using photometry for classification by considering the case of one of the lowest amplitude variables (J123250.33+292123.6) (Fig. 2). Our Johnson B magnitudes are not accurate enough to give an adequate light curve for a variable with such a low amplitude (Fig. 2 (b)(e)). The *NSVS* data in m_R [4],

[3] Both tables are available in their entirety in machine-readable and Virtual Observatory (VO) forms in the on-line journal. A portions of each are shown here for guidance regarding their forms and content.

[4] We use m_R for the unfiltered CCD magnitudes of the *NSVS*

TABLE 1
*ROTSE*1 RR Lyrae variables that are identified in the *GCVS*.

*ROTSE*1 ID	type [a]	Period (days)	m_R [b]	A [c] (mag.)	ID [d]	type [e]	Period [f] (days)
J122907.47+343850.0	rrab	0.55868	13.17	1.0	RR CVn	RRab	0.55860
J123245.60+270145.7	rrab	0.58668	12.20	1.0	S Com	RRab	0.58659
J123556.02+371224.9	rrab	0.66847	12.98	0,7	SV CVn	RRab	0.66806
J123757.13+295805.8	rrab	0.47266	15.02	1.3	FV Com	RRab	0.47246
J124004.01+273014.0	rrc	0.29278	11.57	0.3	U Com	RRc	0.29273
J124055.05+370507.0	rrab	0.44169	13.20	0.8	SW CVn	RRab	0.44165
J124354.34+280114.0	rrab	0.54080	15.11	1.0	DV Com	RRab	0.54084
J124716.30+351206.0	rrab	0.61849	15.10	1.2	DS CVn	RRab	0.61843
J125000.65+310824.4	rrab	0.53654	14.75	1.0	TX Com	RRab	0.53647
J125110.42+325808.3	rrab	0.57463	13.38	0.4	AP CVn	RRab	0.57465
J125421.57+321433.3	rrab	0.51345	14.11	0.9	TY CVn	RRab	0.51344
J125455.50+231526.3	rrab	0.54176	14.82	0.9	BD Com	RR	0.54161
J125952.34+301432.6	rrab	0.53235	14.75	0.9	UW Com	RRab	0.53233
J130129.21+320512.3	rrab	0.55198	14.63	1.1	TZ CVn	RRab	0.55187
J130213.65+241419.6	rrab	0.66163	13.95	0.8	BF Com	RRab	0.66141
J130507.95+231642.8	rrab	0.46901	13.09	0.9	RY Com	RRab	0.46895
J131226.95+302117.9	rrab	0.73723	13.64	0.5	UZ Com	RRab	0.73694
J131703.38+360656.3	rrab	0.67783	15.10	1.0	DZ CVn	RRab	0.67732
J132942.14+285248.2	rrc	0.42518	12.02	0.4	VW CVn	EW	0.85001
J133430.88+291815.5	rrab	0.52353	15.38	1.2	WW CVn	RRab	0.52340
J133455.38+262700.2	rrab	0.57352	15.30	1.3	BT Com	RRab	0.57355

[a] Type given by Akerlof et al. (2000) rrab = RR0; rrc = RR1 .
[b] Unfiltered CCD mean magnitude of variable.
[c] Unfiltered CCD amplitude of variable.
[d] Identification in *GCVS*
[e] Variable type given in *GCVS*
[f] Period given in *GCVS*

however, gives a much better light curve. We compared 12 bright RR Lyrae stars that have both m_R and Johnson BV light curves and found that their m_R, V and B amplitudes are in the ratios of 1.00, 1.27 and 1.60 respectively. The m_R–amplitude of J123250.33+292123.6 is roughly 0.125 mag., so if it were a pulsating star we would expect amplitudes of 0.20 and 0.041 mag. in B and $(B-V)$ respectively. In Fig.2 (a) and (b) we have taken the $(B-V)$ and B curves of the RRc U Com (Heiser, 1996), and scaled them to those of J123250.33+292123.6 using the ratio of their m_R amplitudes; these curves give a poor fit to the data. For an eclipsing system, we would expect the m_R and B amplitudes to be equal and the color to be constant. Our B photometry is not accurate enough to give a reliable amplitude for this star but the small scatter in $(B-V)$ (Fig. 2 (a,d) and the shape of the m_R light curve (Fig. 2 (c,f)), suggests that J123250.33+292123.6 is an eclipsing system with P = 0.52428 days rather than a pulsating star with half this period. A summary of its photometric properties is given in Sec. 2.2.

2.1. *Comments on stars classified as RR Lyrae stars.*

The classifications and periods derived from our photometry agree with those of AAB for the five stars with the highest amplitudes in Table 2. Their light curves are given in Fig. 3 and Fig. 4. Some of the scatter in these light curves may come from using a single period for data that covers five years. Jurcsik et al. (2009) have shown that light-curve modulation is a common property of RR0 (type *ab*) stars and this may also contribute to the scatter (e.g. J123811.00+385028.0 where the modulation is very strong). Comments on the individual stars are given below:

survey.

J123811.00+385028.0: The photoelectric data show that $(B-V)$ varies from 0.25 to 0.35 as would be expected for an RR0 star. Our photoelectric and Tenagra data (2004, 2008 & 2009), however, were inadequate to give a satisfactory light curve. In early 2009, we asked Edward Schmidt to observe the star and he kindly made his observations available to us. The star clearly shows strong Blazhko effect (Fig. 3) but we have been unable to determine the Blazhko period. The adopted ephemeris is JD(max) = 2452407.588 and P = 0.533035 days.

J123854.21+245307.9: Type RR0 (type *ab*). The adopted ephemeris is JD(max) = 2451244.905 and P = 0.628389 days with a V amplitude of 0.33 mag. and $(B-V)$ amplitude of 0.12.

J130441.18+381805.1: Type RR0 (type *ab*). The adopted ephemeris is JD(max) = 2451246.880 and P = 0.686270 days with a V amplitude of 0.85 mag. and $(B-V)$ amplitude of 0.18.

J132849.66+360757.1: Type RR0 (type *ab*). The adopted ephemeris is JD(max) = 2452407.365 and P = 0.586186 days with a V amplitude of 0.73 mag. and $(B-V)$ amplitude of 0.10.

J133048.36+335353.8: This is the only confirmed RR1 (type *c*). The adopted ephemeris is JD(max) = 2451274.511 and P = 0.353000 days with a V amplitude of 0.42 mag. and $(B-V)$ amplitude of 0.15.

In all cases the light curves are significantly asymmetric and there is a significant color amplitude so that the RR

TABLE 2
*ROTSE*1 RR Lyrae variables that are not identified in the *GCVS*.

*ROTSE*1 ID	type [a]	Period [b] (days)	JD Max [c]	D [d]	m_R [e]	A [f] (mag.)	Q [g]	Note
J123250.33+292123.6	rrc	0.26217±0.00003	51244.6032	0.5	11.68	0.1	6	(1)
J123811.00+385028.0	rrab	0.53331±0.00006	51246.6095	0.2	13.94	1.1	5	(2)
J123854.21+245307.9	rrab	0.62841±0.00014	51244.9048	0.4	13.24	0.3	9	(3)
J124855.82+331934.5	rrc	0.20415±0.00002	51244.8268	0.5	12.51	0.2	5	(4)
J125947.50+365843.6	rrc	0.30817±0.00002	51244.5879	0.2	10.62	0.3	5	(5)
J130441.18+381805.1	rrab	0.68636±0.00011	51246.8109	0.3	14.03	0.9	9	(6)
J130705.50+365757.1	rrc	0.22348±0.00002	51244.5912	0.4	11.59	0.2	5	
J132849.66+360757.1	rrab	0.58633±0.00016	51246.6046	0.5	14.87	0.8	6	(7)
J133048.36+335353.8	rrc	0.35292±0.00005	51246.6543	0.5	14.30	0.7	5	(8)
J133204.15+385533.7	rrc	0.28913±0.00007	51244.8027	0.9	11.16	0.1	5	(9)
J133234.47+351949.5	rrc	0.35983±0.00006	51244.4898	0.5	13.14	0.3	6	

Note. — **01** TYC 1991-1673-1 (Hog et al. 2000); BD +30 2289
02 BPS BS 17141-0020 (Beers et al. 1996)
03 Period = $0.^d62839$, [Fe/H] = –1.2 (Kinemuchi et al. 2006)
04 No. 213 (Slettebak & Stock 1959); A-F 140 (Sanduleak 1988
05 BD +37 2346; TYC 2534-1296-1 (Hog et al. 2000); A-F 813 (MacConnell et al. 1993). Häggkvist & Oja (1973) give $V = 10.19$, $B - V = +0.21$ & $U - B = 0.10$ appropriate for Main Sequence star.
06 BPS BS 16938-0026 (Beers et al. 1996) Period = $0.^d68511$, [Fe/H] = –2.2 (Kinemuchi et al. 2006)
07 A-F 930 (MacConnell et al. 1993); BPS BS 16924-0007 (Beers et al. 1996). Period = $0.^d58620$ (Kinemuchi et al. 2006)
08 A-F 938 (MacConnell et al. 1993); BPS BS 16924-0010 (Beers et al. 1996)
09 TYC 3025-723-1 (Hog et al. 2000); BPS BS 17450-0019 (Beers et al. 1996)

[a] Type given by Akerlof et al. (2000) rrab = RR0; rrc = RR1 .
[b] Period in days (and error)
[c] Julian Date of maximum light (+2400000.)
[d] Accumulated phase error after 3 years.
[e] Unfiltered CCD mean magnitude of variable.
[f] Unfiltered CCD amplitude of variable.
[g] Quality on scale 10 (excellent) downwards

TABLE 3
Photoelectric photometry of *ROTSE*1 variables in Table 2.

*ROTSE*1 ID	JDH [a]	V [b]	$(B-V)$ [c]	Phase [d]
J123250.33+292123.6	52407.8184	11.422	0.378	0.691
J123250.33+292123.6	52408.8117	11.371	0.374	0.585
J123250.33+292123.6	52409.6892	11.450	0.376	0.259
J123250.33+292123.6	52411.6874	11.414	0.380	0.071
J123250.33+292123.6	52411.7903	11.440	0.377	0.267
J123250.33+292123.6	52416.7395	11.457	0.375	0.707
J123250.33+292123.6	52417.7894	11.419	0.367	0.709
J123250.33+292123.6	52418.7218	11.440	0.373	0.488

[a] Heliocentric Julian Date (+2400000.)
[b] Johnson V magnitude
[c] Johnson $(B-V)$ color
[d] Phase for ephemeris given in text.

TABLE 4
Tenagra CCD photometry of *ROTSE*1 variables in Table 2.

ROTSE1 ID	JDH [a]	V [b]	B [c]	Phase [d]
J123250.33+292123.6	54543.8937	···	11.77	0.993
J123250.33+292123.6	54574.7290	···	11.82	0.808
J123250.33+292123.6	54575.6632	···	11.85	0.590
J123250.33+292123.6	54578.7472	···	11.66	0.472
J123250.33+292123.6	54579.6928	···	11.77	0.276
J123250.33+292123.6	54580.7074	···	11.85	0.211
J123250.33+292123.6	54845.0301	···	11.75	0.374
J123250.33+292123.6	54846.0272	···	11.83	0.276
J123250.33+292123.6	54847.0444	···	11.83	0.216
J123250.33+292123.6	54847.0548	···	11.85	0.236

[a] Heliocentric Julian Date (+2400000.)
[b] Johnson V magnitude
[c] Johnson B magnitude
[d] Phase for ephemeris given in text.

classification seems secure.

2.2. *Comments on stars classified as eclipsing binaries.*

The remaining six stars in Table 2 have m_R amplitudes of ≤ 0.3 magnitudes and were classified by AAB as RR1 (type c) variables. They do, however, have a very low amplitude or constant $(B-V)$ and so it is unlikely that they are pulsating stars. Support for this comes from their m_R light-curves which use *NSVS* magnitudes[5]. We used a periodogram program (Horne & Baliunas 1986) to find the periods; these were close to those given by AAB. We then doubled these periods before deriving the light curves (Fig. 5). In all cases, this double period gave two

[5] As noted in Sec. 3, we omitted the *NSVS* magnitudes that have large errors and combined those that have closely similar epochs.

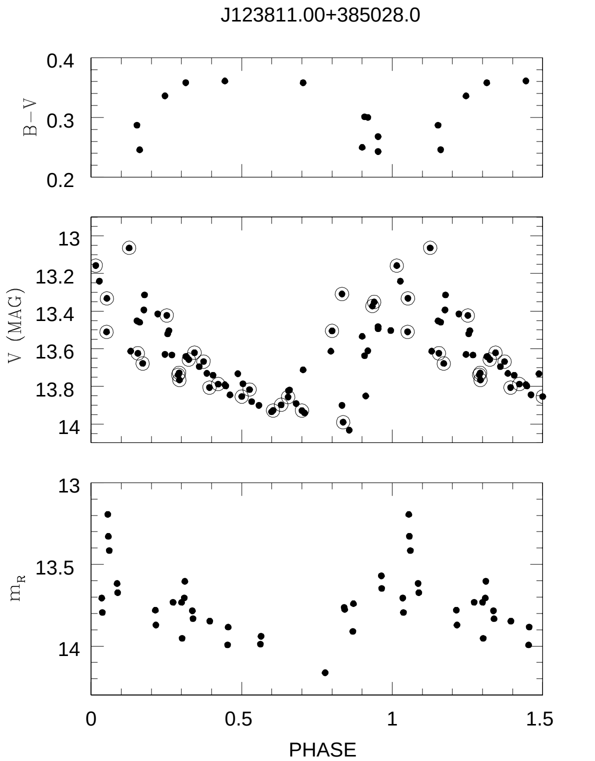

FIG. 3.— Light curves for the RR Lyrae star J123811.00+385028.0. Upper panel: $(B-V)$ from Lowell photooelctric data (2002). Middle panel: V magnitudes. The Lowell photoelectric data (2002) and the Tenagra CCD data (2004, 2008 & 2009) are shown by filled circles. The CCD data (2009) made available by E. Schmidt are shown encircled. Lower panel: m_R magnitudes from *NSVS* (1999).

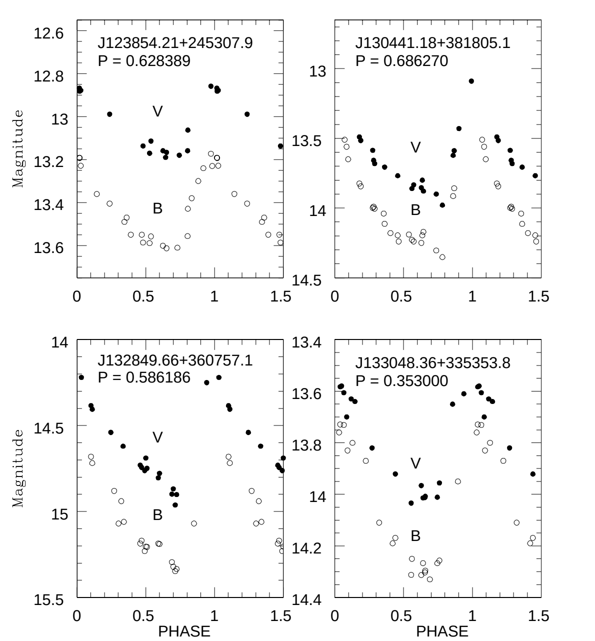

FIG. 4.— Light curves for J123854.21+245307.9, J130441.18+381805.1, J132849.66+360757.1 and J133048.36+335353.8. They are based on both the Lowell photoelectric and Tenagra CCD data and cover the years 2002, 2004, 2008 and 2009. V magnitudes are shown as filled circles and B magnitudes as open circles. All these stars are classified as RR Lyrae stars.

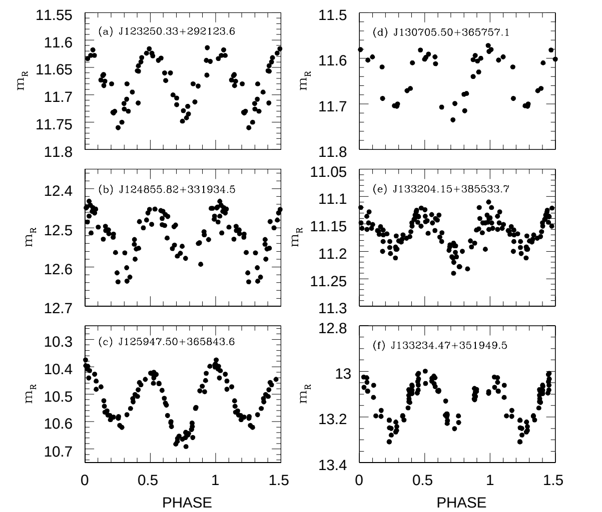

FIG. 5.— Light curves for J123250.33+292123.6, J124855.82+331934.5, J125947.50+365843.6, J130705.50+365757.1, J133204.15+385533.7 and J133234.47+351949.5. The m_R magnitudes were taken from the *NSVS*. All these stars are reclassified as eclipsing binaries.

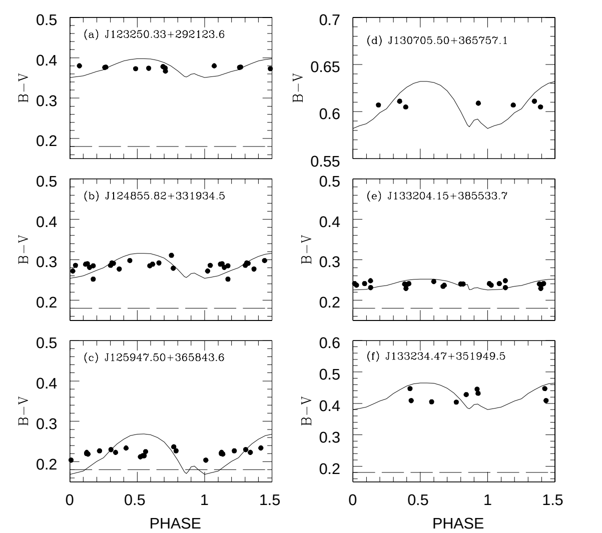

FIG. 6.— $(B-V)$ curves for J123250.33+292123.6, J124855.82+331934.5, J125947.50+365843.6, J130705.50+365757.1, J133204.15+385533.7 and J133234.47+351949.5. The $(B-V)$ colors are the Lowell (2002) observations. The curves are those expected for RRc variables and were obtained by scaling the U Com colors (as in Fig. 2). The dashed horizontal line shows the mean $(B-V)$ of U Com which is generally much bluer than those of these variables. All these stars are reclassified as eclipsing binaries.

minima of slightly unequal depth at phases 0.25 and 0.75 and the the maxima were sometimes somewhat flattened. Fig. 6 shows the Lowell $B-V$ observations for these stars together with the color curves that would be expected if these stars were RRc. As in Fig.2, these curves were obtained by scaling the colors of U Com and the dashed horizontal line shows the mean $(B-V)$ color of U Com. The colors of these variables are generally significantly redder than that of U Com and do not show the phase variation of this RRc.

Details for the individual variables are given below:

J123250.33+292123.6: (A) The adopted ephemeris is JD(max) = 2451244.603 and P = 0.524280 days. The

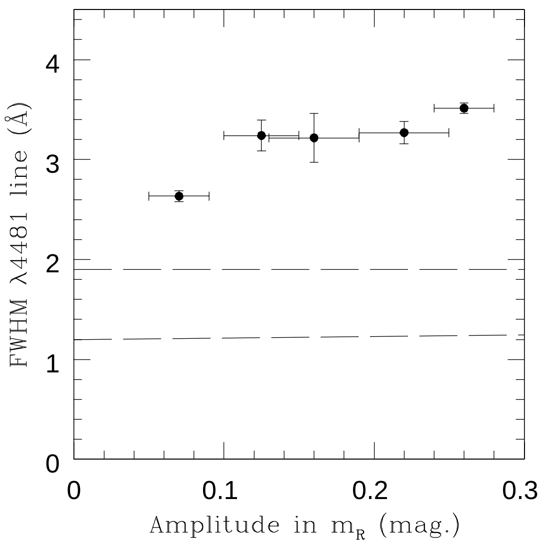

FIG. 7.— The ordinate gives the FWHM line-width in Å of the Mg II λ4481 doublet for the five eclipsing systems for which spectra are available. The abscissa is the m_R-amplitude. For eclipsing binaries, this amplitude should be least for the stars that are seen nearly pole-on and which therefore should show the least line broadening. The dashed horizontal lines show the measured range of line widths for the RR Lyrae stars for which the broadening should be very small.

m_R-amplitudes are roughly 0.110 and 0.125 magnitudes. $< (B-V) > = 0.375$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.004mag.

J124855.82+331934.5: (E) The adopted ephemeris is JD(max) = 2451244.827 and P = 0.408280 days. The m_R-amplitudes are roughly 0.11 and 0.16 magnitudes. $< (B-V) > = 0.286$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.012mag.

J125947.50+365843.6: (G) The adopted ephemeris is JD(max) = 2451244.609 and P = 0.616285 days. The m_R-amplitudes are roughly 0.20 and 0.26 magnitudes. $< (B-V) > = 0.222$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.009mag.

J130705.50+365757.1: (I) JD(max) = 2451244.614 and P = 0.44721 days. The m_R-amplitudes are roughly 0.11 and 0.13 magnitudes. $< (B-V) > = 0.608$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.003mag. The $< B-V) >$ color is too red for this to be an RR Lyrae star.

J133204.15+385533.7: (M) JD(max) = 2451244.790 and P = 0.578340 days. The m_R-amplitudes are roughly 0.05 and 0.07 magnitudes. $< (B-V) > = 0.239$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.005mag.

J133234.47+351949.5: (N) JD(max) = 2451244.454 and P = 0.720306 days. The m_R-amplitudes are roughly 0.18 and 0.22 magnitudes. $< (B-V) > = 0.424$ mag. and the *rms* scatter in $(B-V)$ of a single observation = 0.018mag.

All the above stars are *reclassified* as eclipsing binaries.

3. SPECTROSCOPY

Spectra can be used to distinguish high-metallicity foreground eclipsing stars of the disk from low-metallicity variables that belong to the extended low-rotation halo. We obtained short integrations with the MMT blue-channel spectrograph of all the stars in Table 2 except J130705.50+365757.1. Details of these flux-calibrated spectra (that cover $\lambda\lambda$ 3600 – 4500 Å) are given in Table 5. The spectral resolution was 1.0 Å for all the spectra except those of J133204.15+385533.7 and J133234.47+351949.5 for which it was 1.2 Å. The spectra have S/N in the range 50 to 100 and yield radial velocities with accuracies of 2 to 3 km s^{-1}; the Balmer lines and Ca II K-line equivalent widths can be used to determine the metallicity ([Fe/H). No calibrating standard stars were observed, however, so we could only measure pseudo equivalent widths from which non-standard metallicities were derived. We denote these by [m/H]*.

3.1. *Metallicities and Rotations*

Preston (1959) showed that the difference between the spectral types of the Balmer lines and the Ca II K-line of RR Lyrae stars at minimum light gives an index (ΔS) that measures the metallicity of the star. These spectral types should be derived from the equivalent widths using a calibration given by spectra of stars of known spectral type that are taken concurrently with those of the program stars. Since we had no standards, we used the equivalent width *vs.* spectral type calibration given by Kinman & Carretta (1992); the resulting non-standard indices (denoted by ΔS^*) were converted to [m/H]* using the calibration of Suntzeff et al. (1994). These metallicities are approximate not only because of the rough calibration of the equivalent widths but also because some of the spectra were taken at phases near maximum light where the conversion of ΔS to [Fe/H] is known to be inaccurate. Despite these limitations, the mean ΔS^* for the RR Lyraes (+4.6 ± 1.0) differs significantly from that of the eclipsing stars (–1.9 ± 1.8) in the sense that the RR Lyrae stars have halo abundances ([Fe/H]<–0.8) while those of the eclipsing stars are more nearly solar (Table 5).

The metallicities of RR Lyrae stars can also be derived from their light-curves. Smooth curves (drawn by eye through the data points) were used to derive the Fourier coefficient ϕ_{31}, the V-amplitude and the rise-time. Non-standard metallicities [m/H]* were then derived from these quantities using the equations (3), (6) and (7) respectively of Sandage (2004). The use of hand-drawn light curves necessarily gives approximate results but we see (Table 6) that these three metallicity estimates not only agree well among themselves but also with the spectroscopic values. Our adopted [m/H]* is based on the three photometric and the spectroscopic values. Also, the [m/H]* of –0.9 and –1.9 that we adopt for J123854.21+245307.9 and J130441.18+381805.1 are in reasonable agreement with the –1.2 and –2.2 respectively that Kinemuchi et al. (2006) give for these stars.

We also measured the width (FWHM of a gaussian fit) of the Mg II λ4481 doublet (Table 5). This width is frequently used as a measure of rotational broadening (Slettebak, 1954). In our data, this width is significantly larger for the eclipsing systems than for the RR Lyrae stars. The RR Lyrae stars are known to have quite narrow lines (Peterson et al., 1996) while those of the eclipsing systems should be broadened both by rotation and orbital motion. This broadening should be least for those that are seen pole-on and thus for those with the

TABLE 5
SPECTROSCOPIC DATA FOR VARIABLES OF TABLE 2.

*ROTSE*1 ID	Type [a]	JD(hel.)[b]	Int. [c]	ϕ [d]	R.V. [e] km^{-1}	EW(H)* [f] Å	EW(K)* [g] Å	ΔS^{*}[h]	λ4481 W [i] Å
RR Lyrae stars:									
J123811.00+385028.0	RR0	822.0584	90	0.665	–139	07.5	03.5	+3.5	1.8
J123854.21+245307.9	RR0	822.0550	45	0.573	–118	06.5	05.2	+2.3	1.9
J130441.18+381805.1	RR0	823.0601	90	0.039	–019	09.2	01.0	+7.5	1.2
J132849.66+360757.1	RR0	823.0568	120	0.033	–272	09.5	02.3	+3.8	1.7
J133048.36+335353.8	RR1	823.0545	90	0.533	–128	10.0	01.4	+5.9	1.9
Eclipsing systems:									
J123250.33+292123.6	EW	823.0637	60	0.476	+-32	10.1	05.2	–3.8	3.2
J124855.82+331934.5	EW	822.0607	75	0.716	–065	12.8	03.6	–3.9	3.2
J125947.50+365843.6	EW	822.0635	40	0.064	–040	14.4	02.9	–5.4	3.5
J133204.15+385533.7	EW	920.0232	60	0.797	+004	10.0	03.7	–0.2	2.6
J133234.47+351949.5	EW	920.0210	90	0.564	–039	03.9	06.2	+3.7	3.1

[a] Type derived by our photometry: RRab = RR0; RRc = RR1 .
[b] Heliocentric Julian Date of mid-exposure (+2454000.0).
[c] Integration time in seconds.
[d] Phase of mid-exposure.
[e] Heliocentric radial velocity in km s^{-1}. In the case of the RR Lyrae stars this has been corrected to the γ-velocity following Liu (1991).
[f] Mean pseudo equivalent width of H_γ & H_δ (Å).
[g] Pseudo equivalent width of Ca II K-line (Å).
[h] Non-standard ΔS index.
[i] FWHM of Mg II λ 4481 line (Å).

TABLE 6
DERIVED PHOTOMETRIC AND SPECTROSCOPIC PROPERTIES FOR STARS IN TABLE 2.

*ROTSE*1 ID	type [a]	ϕ_{31} [b]	[m/H]* [c]	[m/H]* [d]	[m/H]* [e]	[m/H]* [f]	[m/H]* [g]	M_v [h]	Dist. [j] (kpc)	V [i] km^{-1}
RR Lyrae stars:										
J123811.00+385028.0	RR0	2.39	–0.96	–0.74	–0.84	–0.66	–0.8	+0.69	3.70	–180±055
J123854.21+245307.9	RR0	2.67	–0.77	–0.85	–1.01	–0.80	–0.8	+0.68	2.89	–189±047
J130441.18+381805.1	RR0	1.94	–1.6:	–2.14	–2.07	–1.59	–1.9	+0.44	4.17	–340±067
J132849.66+360757.1	RR0	2.54	–1.0:	–0.82	–1.35	–0.90	–1.0	+0.65	6.02	–435±300
J133048.36+335353.8	RR1	2.43	–1.36	–1.8:	···	···	–1.4:	+0.57	2.75	–115±044
Eclipsing systems:										
J123250.33+292123.6	EW	···	···	···	···	···	···	+2.43	0.62	+025±04
J124855.82+331934.5	EW	···	···	···	···	···	···	+2.68	0.79	–004±16
J125947.50+365843.6	EW	···	···	···	···	···	···	+1.68	0.49	–064±03
J130705.50+365757.1	EW	···	···	···	···	···	···	+3.46	0.37	(–022±26)
J133204.15+385533.7	EW	···	···	···	···	···	···	+1.88	0.58	–007±04
J133234.47+351949.5	EW	···	···	···	···	···	···	+1.99	1.45	–072±16

[a] Type derived by our photometry: RRab = RR0; RRc = RR1 .
[b] Fourier coefficient derived from hand-drawn light curve.
[c] non-standard [m/H] derived from the spectra.
[d] non-standard [m/H] derived from the Fourier coefficient ϕ_{31}.
[e] non-standard [m/H] derived from the V amplitude.
[f] non-standard [m/H] derived from the Rise-time (phase difference between minimum and following maximum).
[g] Adopted non-standard [m/H]*.
[h] Absolute magnitude derived as described in text.
[i] Distance in kpc.
[j] Galactic velocity vector (V) in km s^{-1}

TABLE 7
DISTANCES AND GALACTIC ROTATIONS ASSUMING THE ORIGINAL CLASSIFICATIONS FOR THE STARS IN TABLE 2.

*ROTSE*1 ID	type [a]	M_v [b]	Dist. [c] (kpc)	V [d] km^{-1}
J123811.00+385028.0	RR0	+0.69	3.70	–180±055
J123854.21+245307.9	RR0	+0.68	2.89	–189±047
J130441.18+381805.1	RR0	+0.44	4.17	–340±067
J132849.66+360757.1	RR0	+0.65	6.02	–435±300
J133048.36+335353.8	RR1	+0.57	2.75	–115±044
J123250.33+292123.6	RR1	+0.86	1.26	+053±09
J124855.82+331934.5	RR1	+0.86	1.90	–003±40
J125947.50+365843.6	RR1	+0.86	0.73	–093±07
J130705.50+365757.1	RR1	+0.86	1.28	(–079±27)
J133204.15+385533.7	RR1	+0.86	0.98	–012±06
J133234.47+351949.5	RR1	+0.65	2.85	–135±33

[a] Type derived by AAB photometry: RRab = RR0; RRc = RR1 .
[b] Absolute magnitude derived from equation (1).
[c] Distance in kpc.
[d] Galactic velocity vector (V) in km s^{-1}

lowest amplitudes. It is seen in Fig. 7, that, in the case of the eclipsing stars, the FWHM of the Mg II λ4481 line does indeed decrease with the decreasing amplitude of the star. Extrapolated to zero amplitude, this width would be about 2.4 Å. This may be compared with the mean width for the RR Lyrae stars (1.7±0.15Å) which presumably is close to the instrumental width.

3.2. *Absolute magnitudes, distances and Galactic rotation*

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Absolute magnitudes for the RR Lyrae stars were obtained from:

$$M_v = 0.214[Fe/H] + 0.86 \tag{1}$$

using the coefficients given by Clementini et al. (2003). Absolute magnitudes for the eclipsing systems were obtained from the calibration for W UMa-type binary stars given by Rucinski (2000):

$$M_v = -4.44 \log P + 3.02(B - V)_0 + 0.12 \tag{2}$$

The distances given in Table 6 are based on these M_v . Then, following Johnson & Soderblom (1987), the radial velocities (Table 5) and proper motions (UCAC3 catalog: Zacharias et al., 2009) were used to calculate the heliocentric galactic rotation velocities (V) given in Table 6. The radial velocities that we give for the RR Lyrae stars in Table 5 have been converted to γ-velocities following Liu (1991). As we noted above, the faintest of our RR Lyrae stars have UCAC3 proper motions whose errors are comparable with the proper motions themselves. Nevertheless, the range in V that we find for the RR Lyraes is quite different from that which we find for the eclipsing stars; they correspond to what we would expect for halo and disk stars respectively.

The galactic rotations in Table 6 are only valid if our reclassications are correct. We have therefore repeated the calculations assuming that the six stars that we have reclassified as eclipsing binaries are in fact RRc stars as originally classified by AAB. The results are shown in Table 7. In this case, the mean galactic rotation of the six stars that we reclassified is –45±31 km s^{-1} and the dispersion in V for these stars is 69±20 km s^{-1}. *Thus, the galactic rotation (V) alone only tells us that these six stars could be disk stars and either be eclipsing binaries or metal-rich disk RR Lyrae stars.* The most doubtful classification is that of J133234.47+351949.5 whose galactic rotation V and metallicity are compatible with it belonging to the halo. The large FWHM of its Mg II λ 4481 line, however, makes it more likely that it is an eclipsing binary.

As would be expected for a disk population, the six stars that we reclassified as eclipsing systems have essentially zero mean radial velocity (–22±20 km s^{-1}). The RR Lyrae stars, on the other hand, show a mean radial velocity that is strongly negative (–135±45 km s^{-1}). This downward streaming of halo stars at the North Galactic Pole was first discovered among subdwarfs by Majewski et al. (1994, 1996). Similar streaming in this part of the sky has since been also found among RR Lyrae and and BHB stars (Kinman et al., 1996, 2006) and the velocities in Table 5 give further confirmation of the effect. This downward motion towards the plane occurs a few kpc above the plane but does not continue to the solar neighborhood (Seagrove et al. 2008); it presumably is one of the many tidal streams that are known to exist in the halo.

4. SUMMARY

We use Johnson *BV* photometry and MMT spectroscopy to study eleven stars (Table 2) classified by AAB as RR Lyraes. Our observations support the RR Lyrae classifications for the five stars with the largest amplitudes, however, we find that the six low-amplitude stars classified by Akerlof et al. (2000) as RR1 (type *c*) should be reclassified as eclipsing binaries. We derive metallicities from both spectra and light curves and find a halo abundance for the RR Lyrae stars and a solar abundance for the eclipsing binaries.

The FWHM line widths of the Mg II λ4481 line provide a clean separation between RR Lyrae stars and eclipsing variables so that, in principle, a single moderate S/N spectrum with a resolution of 1 Å can provide enough information to distinguish between a pulsating variable and an eclipsing binary even when the amplitude is quite low. Supporting evidence comes from the absence of color variation in eclipsing variables, and the differing kinematics of the two types of variables.

Our observations resolve the problematic over-abundance of RR1 (type *c*) reported by AAB. They found that 38% of their RR Lyrae stars were RR1 (type *c*), yet about half this number would have been expected from the Oo I period distribution of these stars. In our 246 deg^2 field, there are 16 RR Lyrae stars with $m_R \leq$ 14.5. We find 4 RR1 (type *c*), including BS Com discussed in Appendix A, and 12 RR0 (type *ab*). Thus in our small sample, 25% of of the RR Lyrae stars are RR1 (type *c*); this is in statistical agreement with that expected from the period distribution. In the future, it would be desirable to investigate the classification of larger samples of the lower-amplitude RR Lyrae stars from the AAB test fields. Also many of the RR1 (type *c*) variables in the *ASAS* catalog are also classified as possi-

ble eclipsing stars; reclassification of these stars using the techniques suggested here would also be very desirable.

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TABLE 8
ASAS-3 VARIABLES WITH PERIODS LESS THAN 1 DAY NOT IDENTIFIED BY AKERLOF ET AL., (2000).

ID (*ASAS*-3)	Class [a]	Period (days)	V_{max} [b]	Amp [c] (mag.)	Other ID [d]	Other Class [e]	$(J-K)_0$ [f]
125534+2553.6	MISC	0.3521	8.92	0.05	IN Com	R:/PN	0.508
131820+2452.3	ED/DSCT	0.4205	10.49	0.50	···	···	0.329
131846+2547.5	MISC	0.3304	9.86	0.59	···	···	1.168
132656+2832.5	MISC	0.6144	11.51	0.23	···	···	0.657
133319+2300.7	DSCT/EC	0.1763	9.22	0.09	···	···	0.378
133439+2416.6	RRC:	0.3631	12.33	0.80	BS Com	RRAB	0.231

[a] Classification in *ASAS*-3: RRC = RR1, DSCT = Delta Scuti, EC, ED = eclipsing system.
[b] V magnitude at maximum light.
[c] V-amplitude in mag.
[d] Identification in *GCVS*
[e] Variable type given in *GCVS*.
[f] 2*MASS* color corrected for extinction.

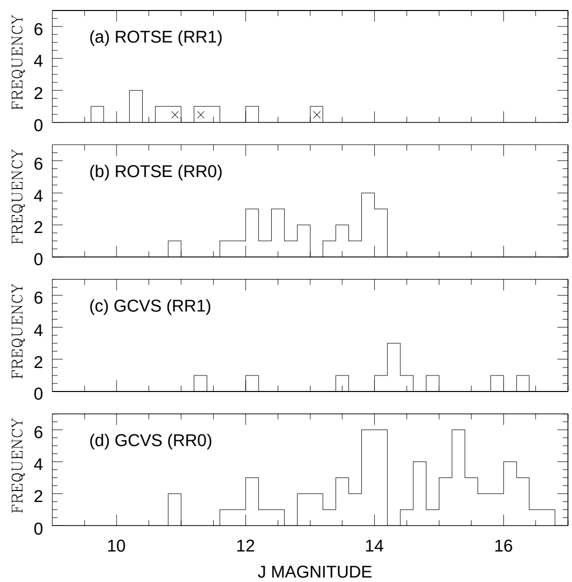


FIG. 8.— The distributions with 2*MASS* J magnitude of RR0 (type *ab*) and RR1 (type *c*) for the *ROTSE*1 survey (panels (a) & (b)) and for the *GCVS* RR Lyrae stars (panels (c) & (d)) in the field of Fig. 1. Unlike their *GCSV* counterparts, the *ROTSE*1 RR1 cover a brighter range than the *ROTSE*1 RR0 stars. The three stars that we classify as RR1 (type *c*) in panel (a) are shown by crosses. We classify the rest of the stars in this panel as eclipsing binaries.

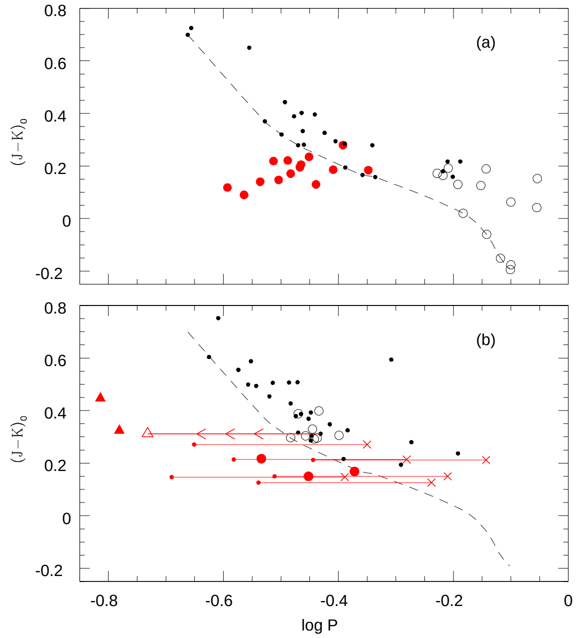
APPENDIX

THE SURVEY FIELD AND PREVIOUS SURVEYS IN THIS LOCATION

Fig. 1 shows the location of our survey field. The declination limits of +23.°0 and +39.°0 and the R.A. limit of 186.°5 were set by the limits of the test field of AAB (Akerlof et al. (2000)). The other R.A. limit (204.°0) was chosen so that the field is roughly symmetrical about the NGP (R.A. 192.°859, Dec. +27.°128). The RR Lyrae stars listed in the General Catalogue of Variable Stars (*GCVS*) are are shown as large open red pentagons. The remaining symbols (in black) show the stars that are listed by AAB according to the following AAB classifications: Filled circles RR0 (type *ab*); open circles RR1 (type *c*); open triangles Delta Scuti stars. The small filled squares are the stars that AAB classified as eclipsing binaries.

Fig. 8 shows the distribution of RR0 (type *a*) stars and RR1 (type *c*) stars as a function of their 2*MASS* J magnitude. These distributions are shown separately for the *ROTSE*1 and the *GCVS* classifications. *The stars classified as RR1 (type c) are generally brighter than RR0 (type ab) in the ROTSE1 survey. This is not true for the GCVS classifications.* In the top panel (a) of Fig. 8, we have markd with crosses the three stars that we classify as RR1 (type *c*); we classify the remainder as eclipsing systems.

The 81 deg^2 of our field South of declination +28.°0 is also covered by the *ASAS*-3 catalogue (Pojmanski 2002). Among the variables with periods of less than a day in the two surveys, there are six stars in *ASAS*-3 that are not given by AAB; they are listed in Table 8. Two of these have amplitudes and colors that make them possible RR Lyrae



cmcm

Fig. 9.— $((J-K)_0$ *vs.* logarithm of period (days) for (a) stars in the local neighborhood and (b) for stars in the field of Fig. 1. Eclipsing systems are shown either by small filled or large open (black) circles. RR Lyrae stars shown by large filled red circles. Stars that we re-classified as eclipsing binaries are shown in (b) as red crosses. Delta Scuti stars are shown by triangles. Horizontal lines show the effect of doubling the period. The dashed curve is the approximate boundary between the eclipsing boundary and the RR Lyrae stars.

stars. 131820+2452.3 is more likely to be a Delta Scuti star than an eclipsing system. The Northern Sky Variability Survey ($NSVS$) data between 1999 April and 1999 July show that the 0.21-day period gives a better light curve than the 0.42-day period (Fig. 10). With such a low amplitude (∼0.1 mag.), however, this result is only provisional but the star is unlikely to be an RR Lyrae variable. 133439+2416.6 (BS Com) has recently been shown to be a double-mode RR Lyrae star with fundamental and overtone periods of 0.487 and 0.363 days and amplitudes of 0.12 and 0.23 magnitudes respectively (Braggaglia et al. (2003); Wils, (2006) and Szczygiel & Fabrycky (2007)). Dékány (2007) has made detailed observations of BS Com; Fig. 4 in his paper shows how the amplitude of this variable varies through its cycle; an extensive set of data is needed to recognize such variables and this, perhaps, is why it was missed by AAB.

Surveys for fainter RR Lyrae stars (roughly $12 < V < 17$) include the Sonneberg surveys which cover the same R.A. range as our field for declinations South of +25.°0 (Meinunger 1977) and the Survey with the Lick Carnegie Astrograph (Kinman et al. 1966) in the region shown by the dotted green lines in Fig. 1. Smaller deep surveys have been made by Pinto & Romano (1973), Erastova (1979) and the CCD transit survey at +28.°0 and width 8.2 arcmin by Wetterer et al. (1996). Most of the stars discovered in these surveys are included in the $GCVS$ and cover roughly half of the total area of our field. The Lick Survey is known to be incomplete for variables with B amplitudes less than 0.75 mag., and this is presumably true of these other *photographic* surveys. In addition to the $ASAS$-3 survey, other new surveys for the brighter variables include the $SAVE$ CCD survey (Maciejewski & Niedzielski 2005) that covers the part of our region with R.A. > 190.°0 and South of +29.°0 and lists five red variables ($9.0 < V < 10.0$) that are not listed in AAB. The $SuperWASP$ survey (Pollacco et al. 2006; Norton et al. 2007) started in 2004 and includes 7.°8 × 7.°8 fields centered on Declination +28.°0 at all R.A.. It uses unfiltered CCDs and includes stars in the magnitude range 8 to 15; a catalog of the variables in this field is being compliled (Norton, *private communication*, May 2009) and should provide a valuable supplement to the $NSVS$ catalog.

The Northern Sky Variability Survey ($NSVS$) has also been searched for RR Lyrae variables by Wils et al. (2006) and by Kinemuchi et al. (2006). In addition to the variables found by AAB, Wils et al. re-discovered the RR0 variables WX CVn ($NSVS$ 7695165) and CY Com ($NSVS$ 7621236).

There are no globular clusters in this field but M 3 is several tidal radii outside the field at R.A. = 205.°546 and Dec = +28.°.376. The RR0 variables in this cluster have 15.49< V < 15.79 and the RR1 variables 15.27 < V < 15.71 (Cacciari et al. 2005). These are too faint to be of concern in this paper.

ON THE CONFUSION OF RR1 (TYPE *C*) VARIABLES WITH CONTACT BINARIES IN THE COLOR-PERIOD PLOT.

Contact binaries form a sequence in a color–period plot (Eggen 1961); Fig 9 shows this plot in the region where confusion between these variables and RR Lyrae and δ-Scuti stars is most likely. Fig. 9(a) gives the plot of $(J-K)_0$ *vs.* log P in which nearby contact binaries (Rucinski 2006; Rucinski & Pribulla 2008) are shown as black filled circles and early type eclipsing systems (Eggen 1961; Eggen 1978) are shown as black open circles. In this paper, magnitudes are corrected for galactic extinction following Schlegel et al. (1998). The black dashed curve shows the lower bound in this plot for the eclipsing systems. Known nearby RR1 (type c) variables are shown in Fig 9(a) by red filled circles and there is a small overlap between these variables and the eclipsing systems on this plot. Fig 9(b) shows the same

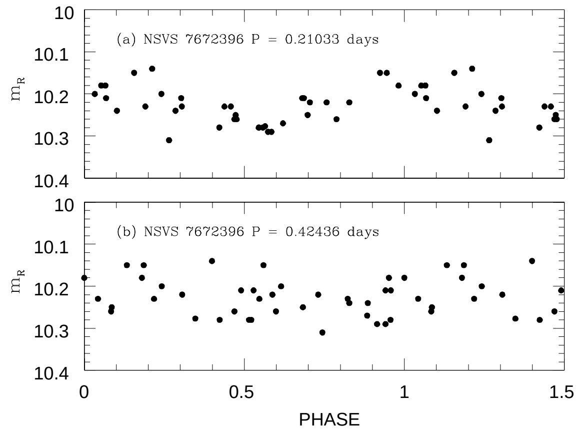


FIG. 10.— Light curves for *NSVS* 7672396 = *ASAS*-3 131820+2452.3. The *NSVS* data (1999 April - July) show that a period of 0.21 days (shown above) is more likely than one of 0.42 days (shown below).

TABLE 9
COORDINATES AND MAGNITUDES OF THE COMPARISON STARS

Variable ID	Comp. Star	R.A. (2000) [a] (deg.)	Dec. (2000) [b] (deg.)	V [c]	B [d]	$(J-K)$
J123250.33+292123.6	A	188.1950	+29.3739	···	14.11	0.346
J123811.00+385028.0	A	189.5251	+38.8471	13.84	14.47	0.365
	B	189.5493	+38.8263	16.53	···	0.662
J123854.21+245307.9	A	189.7609	+24.8800	12.88	13.59	0.407
J124855.82+331934.5	B	192.1793	+33.3364	···	15.97	0.871
	C	192.1750	+33.3493	···	15.92	0.349
J125947.50+365843.6	B	194.9810	+36.9774	···	15.71	0.546
	C	195.0234	+36.9740	···	15.72	0.664
J130441.18+381805.1	A	196.1448	+38.3304	13.85	14.52	0.409
	B	196.2226	+38.3380	15.49	···	0.568
J130705.50+365757.1	A	196.8192	+36.9761	···	14.13	0.587
	C	196.7330	+36.9523	···	15.44	0.234
J132849.66+360757.1	A	202.2527	+36.0687	12.84	···	0.663
	B	202.2017	+36.1046	14.93	15.70	0.539
	C	202.2241	+36.0924	14.97	15.56	0.395
	D	202.2494	+36.0835	13.79	15.56	0.615
J133048.38+335353.8	A	202.6450	+33.8598	15.02	15.73	0.351
J133204.15+385533.7	A	203.0287	+38.9695	12.06	12.31	0.109
	B	203.0538	+38.8945	14.48	15.02	0.342
J133234.47+351949.5	A	203.1228	+35.3107	16.48	17.54	0.734

[a] R.A. in decimal degrees
[b] Dec. in decimal degrees
[c] V magnitude
[d] B magnitude

plot for the $ROTSE1$ data. Here two Delta Scuti stars are shown by red filled triangles. The red open triangle is a star (V_{max}= 11.80, $V-$amplitude 0.37 mag.) at $13^h\ 12^m\ 29^s$; $+25^\circ\ 14'\ 30''$ that is classified as a Delta Scuti variable (Period 0.1854 days) in the *ASAS*-3 Survey (Pojmanski 2002) and as a eclipsing variable (P = 0.37089 days) in the $ROTSE1$ Survey. The three stars that we have classified as RR1 (type *c*) are shown by large filled red circles. The six stars that AAB classified as RR1 would be located by the small filled circles if this classification were correct and by the large crosses if they are (as we believe) eclipsing systems. It is seen that their reclassification as eclipsing systems relocates them in the color–period plot to a place that should be well populated by eclipsing stars.

THE COMPARISON STARS

Table 9 gives the positions and adopted magnitudes for the comparison stars for the variables that are discussed in Sec. 2. The positions are from the UCAC3 catalog (Zacharias et al., 2009) except for that of the comparison star of J133234.47+351949.5 which is from the *NOMAD* catalog (Zacharias et al. 2004). The $(J-K)$ color is taken from the 2MASS catalog.